is necessary to examine upon what principles any improvements attempted in boilers should proceed. In steam navigation, diminished bulk, weight, and con sumption of fuel, are all objects of the first importance, as also in locomotive engines on land.

To make a little boiler generate a great deal of steam in a very short time, is a very difficult matter. Let any one take a common open caldron, or boiler such as is used to boil a few gallons of water ; sup pose the vessel to hold 84 gallons

of water, to be set on a fire so that 9 or 10 feet of its bottom surface are exposed to the fire ; then he will find that he cannot turn more than about 6 or 7 gallons of water an hour into steam. By blowing the fire violently, this quantity may be exceeded, but with a great waste of coal : and it will require a very good chimney, with an excellent draught, to produce even 6 gallons an hour in steam, which is about the quantity of water an hour required to furnish steam for an engine of one horse power; 6 gallons an hour being nearly one cubic foot.

Suppose, then, a greater quantity of steam is to he produced ; how is that to be obtained ? The answer is this: only by a larger boiler and a larger fire, acting on a larger surface. This general statement must be under stood in the following way.

A larger boiler, calculated to generate more steam, does not exactly mean one which holds more water. It is found that the power of the boiler depends primarily upon the extent of its exposure to the action of the fire, or, as it is generally designated, the extent of heating surface. It appears that the heat cannot penetrate through the material of the boiler with more than a cer­tain rapidity, and that the water evaporated over each square foot by the heat passing through, is not more than about 3/5ths of a gallon in an hour ; and so it requires some 9 or 10 such feet of heating surface to boil off 6 gallons, or a cubic foot of water, capable of producing one horse power in the steam-engine. Now, for every such foot of heating surface there will be a cor responding generation of steam; and a boiler having 100 square feet of surface exposed to the fire will be capable of evaporating 100 times 3/5ths of a gallon of water an hour, being 60 gallons, and about 10 horse power. The extent of heating surface, and not the quantity of fluid contained in it, is the measure of the power of a boiler.

One great object of improvements in boilers has been, to in crease as much as possible the extent of heating surface without increasing its general dimensions.

One very efficient mode of doing this, is by the adoption of internal flues. Thus Bolton and Watt have inserted a flue in the middle of the large waggon boiler, in the manner shown in figs. 212 and 213 ; so that, after the flame has passed along the bottom of the boiler to the further end, it returns along the flue in the middle of the water to the front,

and then makes an entire circuit of the outside of the

boiler before entering the chimney. Thus, in a boiler 6 feet wide and 8 feet high and 20 feet long, an internal flue 3 feet wide and 3 feet deep, along the whole length, adds about 240 square feet of surface to the boiler, without increasing the bulk of the room taken up by it.

The same plan has been extensively employed in cylindrical boilers, the flame and hot air being made to traverse a hollow tube or cylinder in the interior of the boiler : sometimes several such flues have been used, and these multiflued boilers are now in great repute. Several modifications are given in the figures. The small internal pipes or cylindric flues, surrounded with water, traverse

the whole length of the boiler, and expose a greater quantity of surface of water to the action of heat, in pro portion as the tubes are small and numerous. These tubular-flued boilers are at the present day extensively used. They economize space, and, with a small exterior surface of boiler, generate a large quantity of steam. They are much used in Cornwall, in marine boilers, and in locomotive boilers.

In these boilers a large surface is still exposed to the cold air, and the brickwork in which the fire is placed radiates off a considerable portion of heat, which is lost. To remedy this evil, the furnace has been so contrived that the fire is in the inside of the boiler. This was probably done for the first time by Smeaton, who succeeded in producing almost as high a proportion of steam from fuel as engineers of a more modern date. His portable-engine boiler is represented below, figs. 216, 217. The interior of this haycock boiler contains a hollow ball of cast-iron, in which the fuel is burned. Air enters by an aperture at the bottom, a large cast-iron pipe leads through the water to the door, and another pipe in the opposite direction passes through the water, conducting the products of combustion to the chimney, immediately round which is introduced the fresh supplies of cold water for replenishing the boiler.

But a much better boiler than this, and one indeed which might bear comparison with many boilers of the present day, is one given by Mr Farey as the invention of an unknown author. In the centre of a large old fashioned haystack boiler, figs. 218, 219, is placed a large round furnace, from which there passes a simple rectangular flue, winding round and round the